VOLKMANN'S CONTRACTURE.

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Richard Volkmann,[1] in 1869 and later in 1875, first described a deformity of the hand and wrist resulting from some interference with the blood supply of the flexor group of muscles of the forearm, usually following the application of splints for fracture occurring in the region of the elbow-joint. The involvement of nerve trunks was mentioned, but to these structures the principal changes were not attributed. The condition is usually styled Volkmann's ischemic paralysis, in order to attribute the profound anatomical changes producing this deformity to the existence of a primary myositis of ischemic origin, due to various factors surrounding the individual case. Writers earlier than Volkmann are said to have called attention to this condition, and to Leser[2] undoubtedly belongs the credit of having emphasized the importance of this type of deformity prior to Volkmann's more definite description.

From a review of the literature on the subject which has appeared since Volkmann's first publication, one is led to believe that this deformity is of rare occurrence. Dudgeon,[3] in 1902, searched the literature and reported only fifteen cases. He apparently failed to collect cases occurring outside of England. Powers[4], in 1907, collected 52 cases, and Taylor[5], in 1908, reported 59 cases, but failed to include two cases reported by Ward. Following the completion of this paper comes the last report by Thomas[6], of 107 cases, to which I can add the case operated upon by Taylor and the one to be reported in this paper. This brings the total number of cases of which we have authentic record up to 109. While it appears that this condition is one of rare occurrence, we are led to believe, however, that many more cases have been observed than have found their way into printed reports. Surgeons to many hospitals with large surgical clinics have had the misfortune to observe this deformity, resulting from either the injury itself or the treatment instituted to immobilize the parts. The printed reports of cases come principally from England, Germany, and this country; so that it is apparent that many cases may have occurred in other countries which have never been reported. Following Volkmann's original publication, attention was directed to this subject by the English physicians, notably Littlewood,[7] Page,[8] Barnard,[9] and Dudgeon, the latter having written quite at length on the deformity from a neurological standpoint.

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[1] Billroth's Path. u. Chirurgie, 1869, ii, 846; Centralbl. f. Chirurgie, 1881, viii, 801.

[2] Volk. Sammlung. klin. Vorträge, 1884, No. 249.

[3] Lancet, 1902, p. 78.

[4] Jour. Amer. Med. Assoc., 1907, xlviii, 759.

[5] Annals of Surgery, September, 1908, 394.

[6] Ibid., March, 1909, 330.

There is by no means a unanimity of opinion as to the causative factors producing this deformity, which is not always a true paralysis. Some observers have believed various accidents attendant upon the injury to be the cause of the resulting contracture, while others believe that the malformation is the result of improper treatment, that is, too much splint pressure.

If we term this deformity and physical disuse of the hand, which, as a rule, is out of all proportion to the degree of injury sustained, Volkmann's contracture, we are not bound to confine the primary anatomical changes solely to the muscle tissue. Whether the condition is the result of the profound ischemia of the flexor and pronator muscles of the forearm, resulting in a myositic degeneration with subsequent scar tissue formation due to a mechanical obstruction of the arterial blood supply to this group of muscles, or whether it be due to a disturbance in the integrity of the vascular structures owing to injury sustained by the trauma producing the fracture (Bloodgood), the type of deformity is usually the same. That this condition of marked contracture and loss of flexor motion of the fingers in the affected limb is not always due to a primary myositis, to the exclusion of other causes, I shall show from the case here reported, in which muscle changes were of secondary importance compared with the disturbance in the continuity of the nerve structures.

DEFINITION AND CAUSE. Volkmann's contracture is essentially a deformity of the fingers of the hand, in which the wrist-joint takes part, and comes on rapidly with loss of muscular power of the forearm. Two cases out of 109 have been observed in which the contracture affected the foot, due to injury and involvement of the flexor muscles of the leg. The condition is almost invariably associated with a fracture of the forearm or humerus in the region of the elbow-joint. It is usually observed in young children under the age of fifteen years, although Dudgeon treated a case occurring in a man of twenty; and Wallis[10] and Ward[11] each observed a similar deformity in women of this same age. Slöffer[12] reported a remarkable case in a boy, aged eighteen years.

The fundamental factors producing the condition are interference with the circulation of the muscles of the part, and injury to the nerve structures in close relationship to the involved muscles. That the condition of contracture as seen in the well-developed type is not always primarily of myositic origin is shown by cases following the prolonged application of an Esmarch bandage above the elbow-joint, and by Slöffer's case, in which thrombosis of the axillary artery followed a gunshot wound of the thorax. The ball lodged in the axilla, and injured the artery.

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[7] Lancet, 1900, 290.
[8] Ibid., 1900, 83.
[9] Ibid., 1901, 1138.
[10] Practitioner, 1901, lxvii, 429.
[11] Lancet, 1902, 372.
[12] Wien. klin. Woch., January 3, 1901, 24.

Dudgeon reported pressure sores in seven out of fifteen cases, due to splints too tightly applied. Taylor states that at least 80 per cent. of reported cases have resulted from splint pressure for fractures of the forearm or humerus. Davies-Colley[13] observed pressure sores occurring in his cases, and ascribed this as the specific cause of the contracture. Page believed the deformity to be the result of a combination of pressure, fixation, and ischemia. Although Volkman stated that he had never seen a case result from the use of an Esmarch bandage, but knew it to be a cause, the case reported by Wallis, in which an Esmarch bandage was applied for over an hour, is proof of the influence of this factor in the production of this condition. Anderson believed the prolonged fixation of fractures of the forearm by any form of apparatus that interrupted the free circulation of blood through the muscles and nerves of the part acted as the causative influence producing this type of contracture. Bloodgood[14] doubts the myositis theory resulting from anemia of the muscles, believing that, although such cases undoubtedly do occur, the probabilities are that more cases are due to injury of the bloodvessels at the time of the accident.

It is curious that with the tight application of splints, usually an anterior and a posterior, to the extent of producing a pressure sore, the muscles involved should always be the flexor group, to the total exclusion of the extensors. It is due to this fact that the typical contracture is produced. That the extensors are not, as a rule, involved may be explained on the following anatomical grounds. On the anterior surface of the forearm the soft structures overlie the radius and ulna, forming at the internal aspect of the upper forearm quite a pad of soft tissue. In addition to this arrangement, the body of the flexor group of muscles is chiefly anterior, coming in direct contact with the splint when applied. The relation of a splint on the dorsal surface of the forearm is such that the ulna is interposed between it and the soft tissues, chiefly the extensor group of muscles. It is to the interposition of this bony structure, which undoubtedly receives the splint pressure, that the extensor muscles owe their escape when splints are so tightly applied as to cause a tissue necrosis with the production of a sore. While this reasoning seems adequate to explain the deformity as a direct result of faulty splint adjustment, it does not definitely solve the factors producing a contracture after long application of an Esmarch bandage, or a direct injury to the vessels some distance from the site of the muscle changes. It is reasonable to expect as much damage to the extensors from these causes as the flexor group suffers, and yet such does not appear to be the case. It is therefore apparent that some other factor must obviously enter into the causative influences producing this deformity. Since no other structures are more exposed to injury than the nerve trunks with their close proximity to the arteries, a constriction sufficient to close the large vessels of the brachial region lasting over a long time must necessarily exert marked pressure on the median and ulnar nerves, *and induce a neuritis with subsequent nerve degeneration.* That the extensor muscles do not suffer is due to the fact that the musculospiral nerve, which ultimately distributes branches to this group of muscles, is deeply placed in the upper arm between the triceps muscle and the humerus. In the region of the elbow-joint the nerve is protected by its position between the long extensors of the forearm. It is, therefore, not subjected to as much trauma as the other cords because of their superficial position in the upper arm.

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[13] Guy's Hospital Gazette, 1898, n. s., xii, 460.

[14] Progressive Medicine, December, 1908.

Embraced as it is by the pronator radii teres muscle, the median nerve is practically subjected to the same forces inducing injury as is this structure. It would seem, therefore, that if pressure over this muscle and its associated group is sufficiently great to cause a profound ischemia, the nerve must primarily share the fate of the muscle which encloses it, and suffer degenerative changes to some extent. Sensation of the fingers does prove that the nerve is involved in very many instances, and the occurrence of flexor muscle paralysis with no marked myositic changes strengthens this view. If we accept a primary myositic and neurogenic origin for this type of contracture, we are able to bridge over deficiencies in the causative factors occurring in cases in which the integrity of the muscle structures is less disturbed than that of the nerves. In this way can be explained those cases of Volkmann's contracture in which no fracture existed, or in which no profound changes took place in the muscles.

SYMPTOMS. The symptoms are usually of rapid occurrence, "coming on in half a day or less in very severe cases" (Volkman); but they may be delayed over a period of many days. The promptness with which the hand assumes the condition of contracture, with the characteristic deformity of the fingers, is surprising. If splints have been applied there is usually considerable pain in the forearm and fingers, due to the great pressure, which is augmented by the traumatic swelling of the parts. Some difference of opinion seems to exist in regard to the presence of pain in these cases before the immobilization of the limb is relieved. Dudgeon believes pain is conspicuously absent in most cases, and attributes the progression of the deformity to the lack of interference due to no complaint on the part of the patient. Tightly applied splints for any injury usually cause discomfort, and it is reasonable to suppose that when splints are so firmly adjusted as to produce a pressure sore, the patient will feel decided discomfort and much pain until their removal. This appears to be the experience of most observers of this condition.

It is important to remember that the condition varies in severity in direct proportion to the length of time the splints are allowed to remain applied, and the degree of pressure and injury sustained. It is due to this fact that much difference of opinion exists regarding the prognosis and treatment, because one case may be irreparably damaged before splint removal, while another with prompt treatment may be of a mild type with apparent functional recovery.

The characteristic deformity is usually that of a pronated forearm slightly flexed at the elbow. There is a decided flexion of the hand on the wrist-joint, and an extension of the metacarpal-phalangeal joints. The interphalangeal joints of the fingers and the terminal joint of the thumb are flexed, and the fingers are often buried in the palm of the hand. Extension of the fingers is impossible with the hand extended at the wrist by any justifiable force, and when the wrist is sharply flexed, the extension of the fingers can usually be procured, although in very severe types even complete extension cannot be made in this position. When pronounced myositis has occurred, later there is usually loss of the soft resiliency of the flexor group of muscles, and a greater degree of resistance is present with a board-like sensation. Add to this condition a cicatrized sore at this site, and the thickening of the tissues may be very marked.

Pressure sores may occur on the flexor surface of the upper forearm, and on either aspect of the wrist. In the case here reported, the photographs show the large shell-like scars on both surfaces of the wrist region. The anterior sore involved the superficial flexor tendons and the median nerve, causing a dissolution of their continuity. Schram reported 60 per cent. of pressure necrosis of the skin in his series. If a pressure sore is present, it usually occurs over the flexor surface of the forearm. Splint pressure may also rarely produce a sore on the posterior surface of the forearm near the elbow. These wounds may not always do so, but depending upon their severity, the necrosis may involve nerve and tendon structures and lead to a pitiful case. From his observation of cases of this severe type, it is possible that Davies-Colley ascribed the contracture to the result of a pressure sore.

Before the splints are removed, marked discoloration and swelling of the hand may be observed with bleb formation on the fingers. In old cases the loss of the use of the hand and nerve involvement will produce a shining, glossy skin, which is cold to the touch; if sensation is impaired, accidental burns may result, as occurred in the case presently to be reported. Trophic changes are absent in this condition, and ankylosis of the joints, although sometimes apparent, has never been observed in a true Volkmann's contracture. Shortening of the limb, which is not of infrequent occurrence in cases of long standing, is suggested by Turney as being due to the lack of growth of the bones owing to the diminished support they are required to afford the affected muscles.

NERVE REACTIONS. The normal electrical reactions of both muscles and nerves is thought by Oppenheim[15] and Turney[16] to be an important diagnostic factor. Dudgeon and Hedley[17] believe with Turney concerning this feature of the disease. Depending upon the time of observation and the duration of the condition when examined, the results of electrical examinations of the muscles and nerves will greatly vary and therefore account for the different expressions of opinion. Involvement of nerve trunks was found to exist in sixty-two of the one hundred and seven cases contained in the table of cases collected by Thomas. He believes this lesion was probably present in some of the other cases, as in many papers the details of the examinations were not given.

PATHOLOGY. The histological changes causing this deformity are still a matter of some speculation. Volkmann believed that the deprivation of oxygen to the muscles owing to obstruction of the blood current caused a condition of muscle asphyxia with the subsequent production of a condition simulating rigor mortis. The venous stasis which occurs simultaneously with the occlusion of the arterial current hastens the onset and adds to the severity of the deformity. Raymond Johnson[18] and Riedinger[19] believed the splint-pressure inducing an anemia of the part produced an inflammation and subsequent fibrous degeneration of the muscles. Davies-Colley thought the condition could be largely accounted for by attributing the pathological changes to the pressure sore invading the soft parts of the flexor region of the upper arm. Wallis and Ziegler[20] account for the structural changes by extravasations of blood serum and round cells into the tissues affected, with subsequent fibrous tissue proliferation, causing contracture of the muscle substance. Kraske[21] thought extreme cold could produce this deformity; and Hildebrand[22] and Bloodgood believe that some direct injury or interference with the blood current at the time of the accident, rather than splint pressure, is the underlying cause in most of these cases. Little mention seems to be made of nerve injury, and yet an analysis of the cases with the symptoms resulting from the injury shows early and often severe nerve involvement. Hildebrand suggested that nerve changes might be primary in their origin, but his view was not shared by Bardenheuer,[23] who thought that nerve degeneration followed secondarily. No doubt many cases will show nerve destruction at the time of the accident, in addition to the profound histological changes in the muscles.

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[15] Diseases of the Nervous System, 1904.

[16] Quoted by Dudgeon, Lancet, 1902, p. 78.

[17] Ibid., p. 82.

[18] Lancet, 1898, i, 722.

[19] Sitzungs. Berichte, der phys.-med. Gesellsch. zu Würzburg, 1902, No. 3, 33.

[20] Lehrbuch der Allg. Path., etc., p, 306.

[21] Centralb. f. Chir., 1879, No. 12.

[22] Deut. Ztschr. f. Chir., 1890, xxx, 98.

[23] Centralb. f. Chir., 1906, xxxiii, 505.

The nerves at operation are often found swollen and thickened or so degenerated as to present only a fibrous strand of tissue. Some cases at operation have shown a wasting of the muscles with a pale and dry appearance.

In the case reported herewith the muscle substance which was exposed at operation showed no macroscopic changes which would indicate injury or degeneration. In this case the deep pressure sore on the anterior surface of the wrist had invaded all the superficial flexor tendons and the median nerve. The nerve had been destroyed at the middle of the forearm, and the distal end could not be found at the wrist. Most of the superficial tendons had also been lost through infection.

DIAGNOSIS. A fracture of one or both bones of the forearm or of the lower extremity of the humerus occurring in a child under fifteen years of age accompanied by much swelling, with the immediate application of splints, usually of the anterior and posterior variety, resulting in discoloration of the hand with the presence of much pain, and a tendency for the fingers to contract, should at once suggest the possibility of the presence of a Volkmann's contracture. Removal of the splints will at once present the characteristic features of this deformity, especially if added thereto a pressure wound is seen. Volkmann stated that the paralysis and contracture arise simultaneously, not as in paralysis of nervous origin, in which contraction is a later phenomenon and of gradual onset. While the contracture, as a rule, is of rapid occurrence, the hand assuming the position shown in the photographs, the deformity may be somewhat delayed by the continued use of an anterior splint after the fingers have begun to contract.

At times some difficulty may arise in differentiating a Volkmann's contracture from other conditions in which pure nerve lesions are the underlying causes. In ulnar and median nerve paralysis the prompt loss of sensation in structures to which these nerves are distributed will result. Muscle paralysis will follow at once, depending upon the group of muscles to which the nerve distributes branches. In ulnar nerve paralysis the reactions of degeneration in the wasted muscles are present, but there is no reaction to stimulation with the faradic current. The resulting atrophy of the muscles of the hand, and the development of the so-called "claw-hand" in paralysis of this nerve, will clearly indicate the nature of the lesion.

Trophic lesions may be present, and there is usually no flexion of the wrist in nerve palsies. In musculospiral nerve paralysis there is usually a bilateral wrist-drop, unless the nerve on one side is injured from the surface. The muscles involved in this type of deformity are the extensors of the forearm, and the lesion is easy of recognition.

PROGNOSIS. "There is no more pitiful condition than this after an injury, usually a fracture, in healthy strong children"

(Bloodgood).[24] The prognosis in cases in which the hand and fingers are affected with much deformity is bad, and if nerve involvement is present, as appears to be the case in many instances, the outlook for a good functional result is practically hopeless. Anderson[25] opposed Volkmann's gloomy prognosis and believed that function of the hand and fingers could in a large measure be restored, but he did not cite any cases to substantiate his claim.

The extent of the damage done to the muscles and nerves will in a very large measure determine the outcome of the case, if prompt treatment is instituted. It is due to this fact that early cases with little time for extensive changes to occur have yielded to measures tending to restore the normal tone of the structures involved. Some cases are undoubtedly hopeless from the beginning, and no form of treatment will preserve the use of the affected hand.

TREATMENT. There is apparently wide difference of opinion in regard to the course of treatment to be pursued for the purpose of restoring the hand to its normal appearance. So great has been the difference of opinion as to the specific underlying cause of this type of contracture, and the proper treatment to be undertaken, that we are given Volkmann's almost hopeless prognosis on the one hand, and later the hope expressed by Anderson that it was the exceptional case which did not recover. This difference of view is obviously due to the varying degrees of injury which may be sustained, resulting either in a deformity of almost transient type or one of hopeless contracture and physical disability. When little splint pressure has existed, with only a slight or no break in the continuity of the skin, and prompt recognition of the condition (with measures for relief), the resulting deformity will not be of the type generally seen after the long application of splints with deep pressure wounds involving the muscles, tendons, and nerves. In the latter class of cases any form of treatment will often be of little use, and hence the choice of the many methods of correcting the deformity will vary with the individual case and the skill of the operator. A careful review of the cases tabulated by Dudgeon, Ward and Powers, and later by Thomas, will show some of the best results following an expectant line of treatment supplemented with massage, passive motion, and electricity.

It matters little which factor is foremost in producing this deformity, or whether it can only occur from splint-pressure, and not result from too long application of an Esmarch bandage—the fact remains that the disuse and appearance of the hand resulting from either cause conforms with the contracture first noted by Volkmann, and the correction of the condition confronts the surgeon, who is left to select the operation which best suits the individual case.

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[24] Progressive Medicine, December, 1908.

[25] The Deformities of the Fingers and Toes, p. 66.

In spite of the greatest care, splints properly applied for a fracture of the forearm or humerus near the elbow will often, in a few hours, become tight and uncomfortable from the swelling and œdema of the part. It is, therefore, a wise precaution to see all fracture cases within a few hours after the reduction of the fracture and the immobilization by splint application. If there is discomfort, prompt removal of the dressing and its reapplication, allowing for the swelling of the part, will be the best prophylactic means of obviating the development of this deformity.

The evidence adduced by the experimental work of Lapinsky[26] and Leser[27] tends to prove that the continued immobilization, following tight splint pressure with resulting ischemia of the muscles of the part, is a very important factor in the production of this deformity. Therefore, with the symptoms of this condition, the prompt removal of the splints or plaster bandage is of the first importance. Every effort should be made toward restoring the hand to its normal anatomical and physical appearance. The splints may be left off if necessary, allowing the fracture to care for itself. Passive motion, massage, electricity, and even active motion must be resorted to at intervals of a few hours to correct the condition. A deformity due to the improper reduction of the fracture is of much less significance compared with the severe result from the reapplication of splints if the hand and wrist are already contracted.

Once present, the condition must be carefully studied with a view to determining the extent of muscle, nerve, and tendon involvement. If large and deep pressure sores are present, little can be done until they are healed. When tendon and nerve structures are much involved, and subsequent destruction results, due to infection of the wound, the outlook is almost hopeless from any standpoint, and the loss of time awaiting the healing of the wound is not a great factor in the treatment.

If pressure sores are slight and heal quickly, treatment should be resorted to promptly.

Non-operative Treatment. There are some cases which will probably recover without operative treatment. This class includes cases with slight injury to the muscles and nerves with little resulting deformity, and in which there has been prompt recognition and treatment as suggested. The treatment is often tedious, discouraging at first, and must be carried out over a long period of time, often many months, and sometimes years. In this class of cases the principle measures to be employed are massage, passive and active motion, and electricity, with permanent removal of the splints if deemed necessary. Such cases have been reported by Leser, Niessen,[28] Dudgeon, and others.

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[26] Deut. Ztsch. f. Nervenh., 1900, xvii, 322.

[27] Samml. klin. Vorträge, Leipsic, 1884, p. 249.

The extension of the fingers and hand under an anesthetic as the sole measure of treatment, employed by Volkmann, has proved valueless, and often difficult to accomplish. Mechanical extension of the fingers and hand over a long period of time (Sayre[29]), and continuous elastic traction (Martin[30]), have been employed with good results. Robert Jones,[31] of Liverpool, obtained a good result by separate splinting of the fingers, with flexion at the wrist. By increasing the length of the splints he was enabled eventually to secure extension of the fingers. He believes this gives better results than operative treatment The various means of treatment with the success attained by each tends to prove the assertion that all grades of injury and deformity may occur, to which special types of treatment are adapted.

Operative Treatment. Garré,[32] in 1895, and later Henle[33] and Raymond Johnson, first advised resection of portions of the radius and ulna in order to restore the hand to its normal position. By shortening the forearm the flexion of the fingers and hand at the wrist are overcome and motion is permitted, provided the muscles have not undergone complete fibrous transformation.

In shortening the bones care must be taken to perform the resection at different levels to avoid fixation of the bones from the union of the callous in the interosseous space. This operation is short, and simple in its performance, and has given very good operative relief in many cases in which it has been tried. The danger of non-union (Raymond Johnson) is slight, but shortening of the arm is produced, and if there is much growth of the bones later, some contracture may recur (Erdman[34]).

Tendoplasty. This operation has been successfully employed to overcome the marked flexion present. The English surgeons, particularly Page, Littlewood, Barnard, Wallis, and Ward, have done this operation with marked success, in some cases almost completely restoring the use of the hand. This operation has many warm advocates, and is preferable to resection of the bones in some cases, particularly when the tendons and nerves are involved in the newly formed fibrous tissue affecting the muscles, or in the scar resulting from a pressure sore.

Lengthening of the tendons is a tedious and often difficult operation to perform, but allows of an exploration of the injured structures and a transposition of the ulnar and median nerve if either is found too tightly in the grasp of the scar tissue.

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[28] Deut. med. Woch., 1890, xvi, 796.

[29] Mentioned by A. S. Taylor as presented before the Pediatric Section of the New York Academy of Medicine, March 12, 1901.

[30] Congress Français de Chirurgie, Paris, 1903, xvi, 934.

[31] Amer. Jour. Orthop. Surg., 1908, v, 377.

[32] Deut. med. Woch., 1895, xxxi, 484.

[33] Henle. Quoted by Dudgeon.

[34] New York Surgical Society, April 8, 1908, quoted by A. S. Taylor.

The danger of mistaking tendons and accidentally injuring the nerves in the forearm are somewhat exaggerated, and the chief difficulty in the performance of this operation is the length of time required. If the scar resulting from the pressure sore is large, it should be excised and transplantation of a skin flap done, the upper abdomen being a convenient region from which to utilize the necessary tissue. The latter method was pursued by Dr. Stewart in the case here reported.

Tenotomy. Tenotomy has been practised in a few instances to overcome the deformity present. This measure eliminates all future possibility of obtaining any use of the hand, and while it improves the appearance of the limb, it is doubtful whether this procedure should be followed even after every possible means has been tried to restore the function of the fingers.

These are the principle operative procedures that have been tried for relieving Volkmann's contracture. Prompt relief to nerves which appear to be involved in the scar tissue should be afforded and superficial transplantation done, as recommended by Kleinschmidt[35] and Freeman,[36] who believe in very early nerve involvement in these cases. Bardenheuer believes the nerve changes in these cases are secondary to muscle involvement, and advocates an operation for the purpose of separating the muscles.

Whatever operation may be done to cure the condition, every assistance should be given the patient, following recovery from operation, to restore the use of the hand. For this purpose massage, electricity, and active and passive motion should be tried, and carried out over a long period of time. It is surprising the improvement that will follow after a long course of the above treatment, covering many months and sometimes years. In addition to these means, congestive hyperemia preceding the bath and massage is recommended by Taylor.

The following case was observed and studied by me: J. S., a male, aged twelve years, a school-boy, was first seen on August 30, 1908, in the out-patient surgical clinic of the Philadelphia Polyclinic, in the service of Dr. Francis T. Stewart, to whom I am indebted for the privilege of studying and reporting the case. There are no incidents in the medical history of the case previous to the accident which have any bearing upon the present condition. On August 20 the boy fell out of a second story window and sustained a fracture of the right radius about 3 cm. above the wrist-joint (Colles' fracture). He was treated in the hospital surgical clinic about forty-eight hours after the injury was sustained, when the splints (both an anterior and posterior) which were applied within an hour after the fracture were removed because of great pain, swelling, and discoloration of the fingers of the hand. There were a number of blebs on the palmar surface of the thumb. He had suffered continual pain following the reduction of the fracture and the application of the splints, which increased in severity and then gradually disappeared, to be followed by numbness of the part. Upon removal of the splints, the right hand was observed to be swollen, discolored, and somewhat colder than its fellow. There was a little flexion of the hand on the wrist, and some contraction of the interphalangeal joints of the fingers. The thumb was adducted, and three or four blebs containing bloody serum were present. The deformity was not very marked, because the splints had been very tightly applied by means of strips of adhesive plaster and a bandage of muslin. Over the flexor surface of the wrist there was a large oval pressure sore extending into the subcutaneous structures. A similar sore was present on the dorsal aspect of the wrist, but did not involve the extensor tendons. A slight break in the continuity of the skin just below the elbow-joint, where the upper edge of the posterior splint had pressed, was present, with two or three blebs. There was no pressure wound over the body of the flexor muscles of the forearm.

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[35] Centralb. f. Chirurg., xxxiv, 81.

[36] Surg., Gynec., and Obs., July, 1907.

Some flexion of the forearm at the elbow-joint was present and persisted for several weeks. Motion of the fingers and the hand was very slight, and painful. Skiagraphic examination revealed a fracture of the radius about 3 cm. above the wrist joint, with some anterior projection of the lower fragment.

The posterior splint was removed permanently, and every effort was made to heal the large pressure sore on the flexor surface of the wrist. Any motion of the fingers or hand was attended with such excruciating pain that for the first week the wounds on both surfaces of the wrist were dressed daily and lightly bandaged to an anterior splint extending to the tips of the fingers. The progression of the deformity was rapid, and by the end of the first week the characteristic pronation and flexion of the hand, with contracture of the fingers described, was present. The splint was removed and kept off, and since nothing could be done until the deep wounds healed, the limb was dressed daily and carried in a sling. Infection of the sore on the flexor surface of the wrist followed, and the superficial tendons sloughed away, leaving a thick contracted scar, as shown in the accompanying photographs (Figs. 1, 2, and 3). The healing of this wound occupied many weeks.

At the time the electrical examinations were made by Dr. Spiller, November 15, 1908, the deformity was very marked, and corresponded to the classical description of Volkmann's contracture. The following is Dr. Spiller's report: "J. S. has prompt reaction to faradic current in the right forearm, in the muscles of both flexor and extensor surfaces. There is slight contraction of the flexor and extensor muscles below the wrist. Sensation for touch and pain are greatly impaired below the wrist and apparently normal above the wrist."

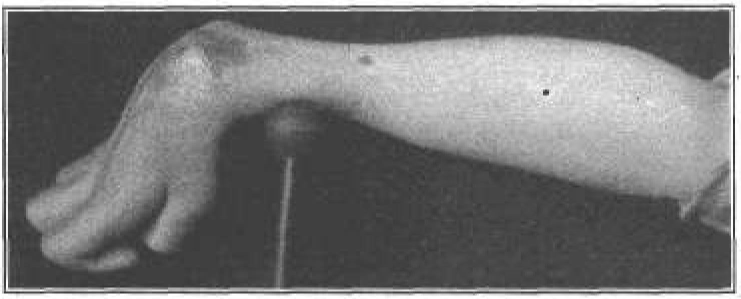

FIG. 1.—A large scar on the dorsal surface of the hand; flexion of the hand at the wrist, and of the fingers at the interphalangeal joints.

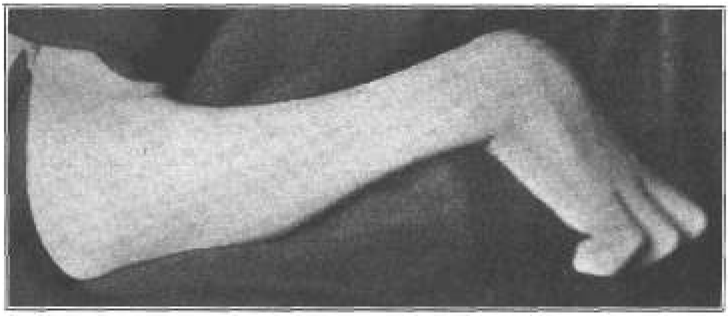

FIG. 2.—Marked pronation of the hand; flexion of the forearm on the elbow, and extension of the fingers at the metacarpal-phalangeal joints.

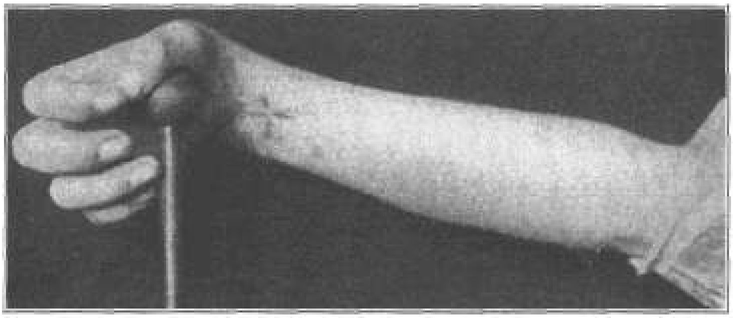

FIG. 3.—A large scar on the anterior surface of the wrist, resulting from the pressure sore; the fingers and thumb present the characteristic contracture observed in this type of deformity.

So greatly was sensation impaired in the fingers of the hand that an accidental burn occurred over the first interphalangeal joints without the knowledge of the patient.

When the pressure sores were finally healed, the hand presented practically a useless appendage, and the tips of the fingers were almost buried in the palm. With complete flexion of the hand on the wrist, the fingers could not be fully extended, and pronation of the hand was marked. Passive and active motion had only succeeded in overcoming the flexion at the elbow.

It was apparent that this case presented a combination of many factors, producing the deformity: involvement of nerve, tendon, and probably muscle structures.

Operation, November 23, 1908, by Dr. Francis T. Stewart. The operation was performed under ether, and required over two hours. Excision of the scar on the anterior surface of the wrist was performed, leaving a large denuded area. The longitudinal incision was carried up to the middle of the forearm, and a careful dissection of the adherent and fibrous structures was made. The tendons of the flexor sublimis digitorum and palmaris longus muscles were absent, and all that remained was their proximal ends. The ulnar nerve was intact and uninjured, and the pulsation of the ulnar artery was feeble. The pronator quadratus was so changed as to present merely a white quadrilateral fibrous structure with no macroscopic remains of muscle tissue. The median nerve was destroyed from the middle of the forearm to below the annular ligament at the wrist, and only the proximal end could be found where it emerged from the mass of the pronator radii teres muscle. The nerve seemed to be continuous with a thin fibrous strand of tissue. The radial pulse was also feeble.

The anterior projection of the lower fragment of the radius formed a sharp ledge, over the border of which the structures were pressed by the tightly applied splints. It is quite likely that this feature of the accident greatly assisted in the subsequent destruction of the tendons and median nerve which followed the primary injury. Incision carried to the flexor muscles showed no macroscopic alteration in their appearance suggestive of a very pronounced myositis.

Tendoplasty was performed, utilizing the deep flexor tendons and the remains of the superficial group of tendons. The fingers and the hand were extended, and the forearm placed midway between pronation and supination. Transplantation of a flap from the epigastric region, leaving one end attached, was done to fill in the large gap left by the removal of the scar on the flexor surface of the wrist. The hand was bandaged across the upper abdomen for ten days, at the end of which time the attached end of the flap was cut and the hand freed.

Postoperative Course. The graft, consisting of the skin and subcutaneous fatty layer, healed promptly and was not followed by a contracted scar. At the end of two weeks active and passive motion were begun, and supplemented with massage, electricity, and baths, which are being continued at the present time. Contracture of the fingers has recurred, but the deformity is not as severe as it was previous to the operation. The thumb is still adducted, but allows of slight motion, and there is some improvement in the extensor and flexor movements of the fingers. Sensation in the hand has distinctly improved, but the limb is very far from being a useful extremity. At this writing, steady improvement has been noted in the recovery of the motion of the fingers. It is to be hoped as time goes on that enough motion of the fingers and hand may be secured to enable the patient to perform the more necessary acts.

In this case we have the contrast of a careful painstaking operation, the purpose of which was to free any adherent structures in the forearm, and to lengthen the tendons, thereby correcting the deformity of the hand, with the operation of resection of portions of the radius and ulna recently performed by Taylor. The operation done in this case was tedious and time consuming, but it seemed preferable to any other procedure. In both cases the ultimate result was poor, owing to the incurable state of the damaged structures. Although improvement is slowly going on, it is extremely doubtful whether in either case complete recovery will ever take place.

CONCLUSIONS. 1. The specific underlying factor producing a Volkmann's contracture is still a matter of dispute; but the evidence seems to warrant the assumption that it is a deformity in which muscle, nerve, and tendon structures share. Early, and probably primarily, the nerve structures share the same injury which induces muscle anemia with subsequent myositic degeneration. The contracture is the result of a myositis, with accompanying nerve lesion, and may vary from a transient type to that of hopeless deformity.

2. This deformity follows, in most cases, too tightly applied dressings for fractures of the forearm or humerus in the region of the elbow-joint, in children under the age of fifteen years. Usually the pressure has been of sufficient intensity to produce a pressure sore, which is present in 80 per cent. of the cases. It may arise within less than twenty-four hours, or be delayed for many days.

3. Severe pain, followed by numbness, discoloration of the hand with bleb formation, and contraction of the fingers are first noticed. Later, the characteristic flexion of the fingers at the interphalangeal joints, with flexion of the hand at the wrist, and marked pronation occur. Some flexion at the elbow is usually present.

4. Careful application of dressings, with frequent inspection, is the best prophylactic measure. Prompt recognition of the symptoms, with measures to restore the hand to its normal appearance,

constitute the safest means of obviating the subsequent development of what may prove to be an irremediable condition. Active and passive motion, massage, and electricity, with permanent removal of the splint, should be advised if deemed necessary.

5. Operative treatment depends upon the individual case. No specific procedure can be suggested, but tendoplasty and resection of both bones of the forearm are the two methods of operative treatment offering the best chance of recovery of use of the hand. The nerves should always be examined to determine the extent of involvement, and should be freed if necessary.

6. The prognosis is unfavorable depending upon the duration of the case and degree of involvement of the damaged structures. Partial recovery is not unusual in cases seemingly hopeless in the beginning.

A CASE OF APPENDICITIS IN WHICH OXYURIS VERMICULARIS WAS FOUND IN THE APPENDIX.[1]

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Laura P., a Polish girl, aged fourteen years, was admitted on March 14, 1909, to the Episcopal Hospital, in the service of Dr. G. G. Davis, to whom I am indebted for the privilege of operating and of recording the case. Owing to the patient's ignorance of the English language, it was difficult to obtain an accurate history, but it was learned that she had been ailing for a week or ten days, and that twenty-four hours before admission she had been taken with severe abdominal pain, followed shortly by vomiting. The pain was at first general, but later settled to the region of the appendix. Examination at 9.30 P.M., soon after admission, showed great tenderness with some rigidity over the right iliac region. No mass was present. The temperature was 100.6° F., the pulse 88, and the respirations 34 per minute. The white blood cells numbered 25,000 per c.mm. The diagnosis was acute appendicitis.

Operation at 10 *p.m.* Through the transverse incision of G. G. Davis,[2] an appendix was removed which was congested at the tip, but presented no other gross evidences of disease. The abdominal wound was closed without drainage. When the appendix was slit open at its tip, the lumen of the organ was found to contain a number of minute worms, resembling "seat worms." Subsequent examination under the microscope by Dr. C. Y. White, director of

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[1] Read at a meeting of the College of Physicians of Philadelphia, April 7, 1909.

[2] Annals of Surgery, 1906, xliii, 106.